Hyperspectral information for vegetation monitoring

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Background – tropical case study

In recent years, our group together with CMCC has been able to collect hyperspectral and lidar data in West African forests, to investigate biodiversity, carbon density, productivity and other vegetation information. These forests have high value and are poorly investigated.

We collected a large number of field information in forest plots:
>700 in Sierra Leone
>90 in Ghana forests
Including tree height, tree species, guilds (NPLD, SB, PION), biomass etc.

cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

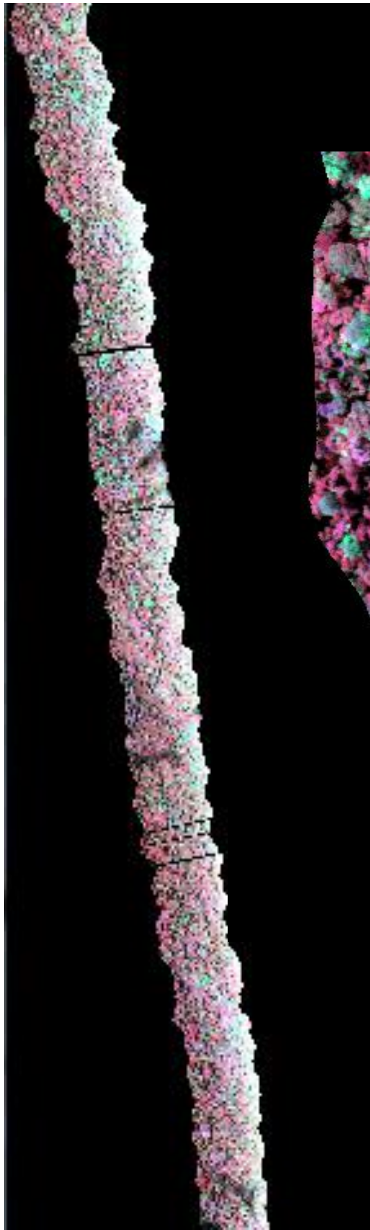
<u>Areas of interest</u>:
Sierra Leone - Gola Rainforest National Park, moist evergreen forest
Ghana – Ankasa National Park, wet evergreen forest
Ghana – Dadieso Forest Reserve, moist evergreen forest
Ghana – Bia National Park and Bia Forest Reserve, moist semideciduous forest

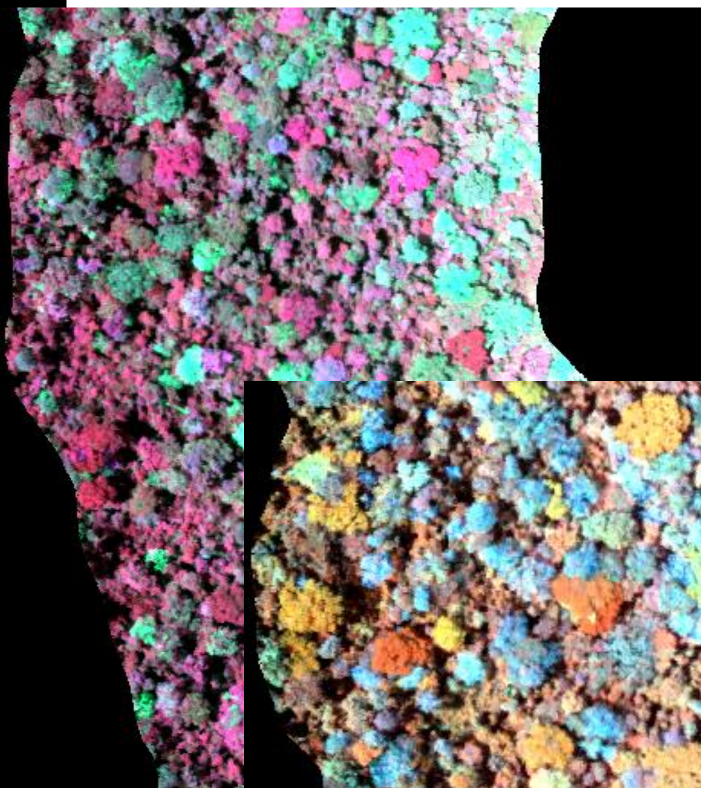
Value of West African Upper Guinean Forests

World Biodiversity Hotspot (CI)
Buffer between Sahel- ocean: fundamental in desertification avoidance
Dramatic decrease of the original extent
High fragmentation due to logging, mining, human use, hunting
Highest human population growth in the world still putting pressure
Affected by climate change, increased and prolonged droughts

Airborne data over field plots

March 2012: field plots were surveyed, using a Pilatus PC-6 Porter aircraft (from Italy!) equipped with lidar and hyperspectral sensors and a digital camera for aerial photographs.





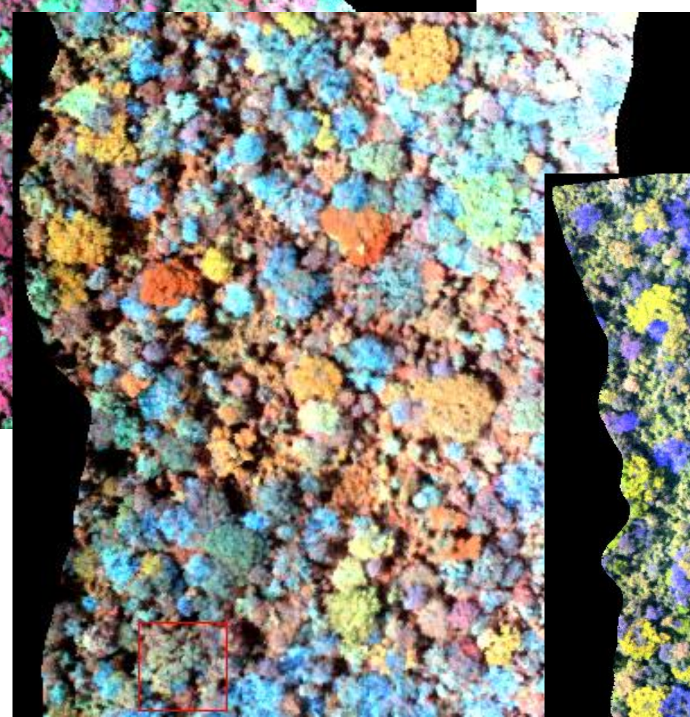
***Hyperspectral*: AISA**

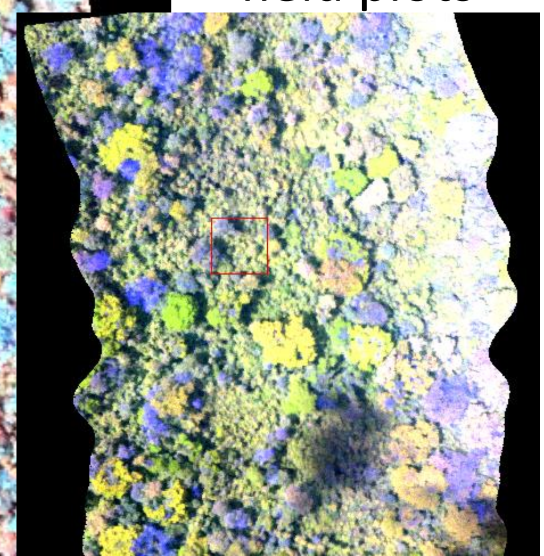
Aigle 244 bands VIS-NIR

1 meter spatial resolution

Spectral range: 400 – 974 nm

Flight strips covered a 80m buffer around field plots





Hyperspectral processing

- AISA Eagle sensor, FOV 39.7°, 244 bands reduced to 186 for noise, 2.3 nm spectral res., 400–970 nm.
- Final spatial resolution 1 m, after radiometric corr. and orthorect. (lidar DEM)
- Atmospheric correction using FLAASH algorithm in ENVI.
- Minimum Noise Fraction (MNF) transformation to further reduce noise. For each image strip, 9–15 MNF components were selected by visual screening to compute the inverse MNF to transform back bands in the original data space.
- Eight vegetation indices (VIs) were calculated from the inverted MNF bands, representing information of vegetation greenness, light use efficiency and leaf pigments and selected for being relatively insensitive to shadow.

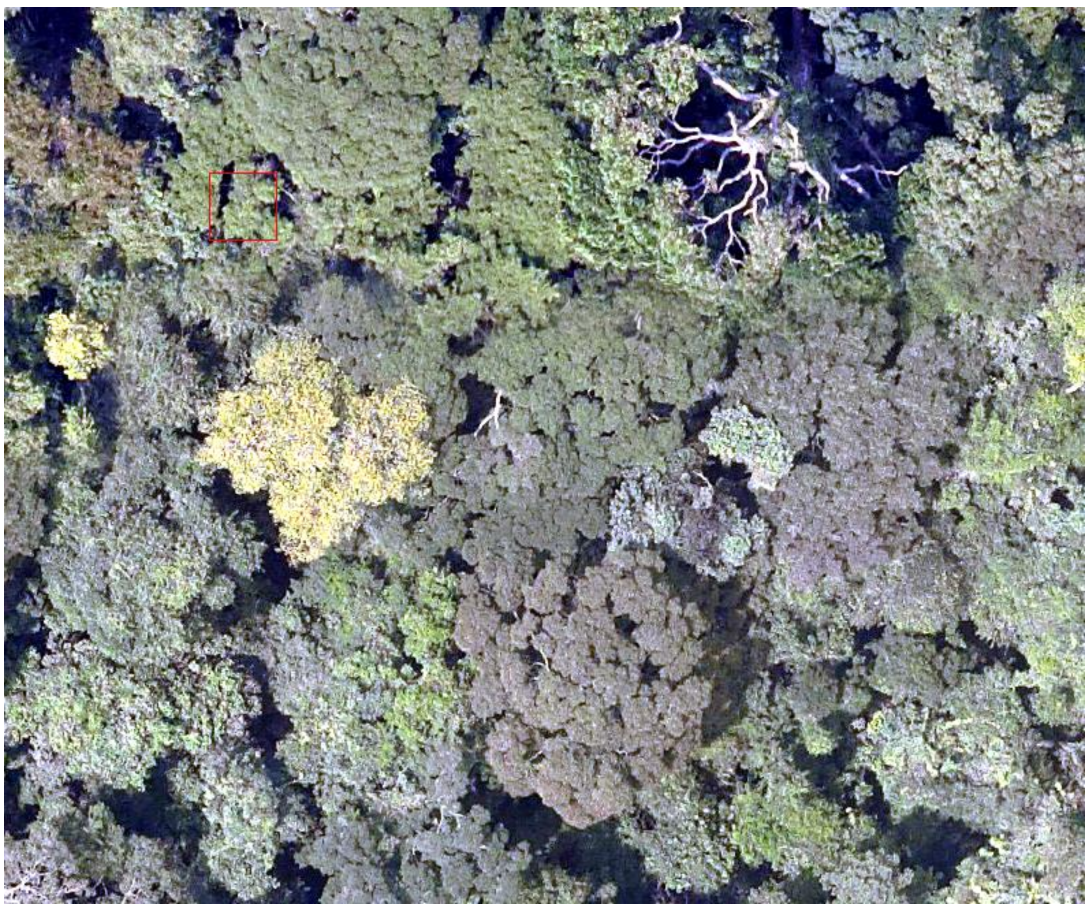
Normalized Difference Vegetation (NDVI) and Simple Ratio (SRI), Atmospherically Resistant Vegetation (ARVI), Red Edge Normalized Difference Vegetation (ReNDVI), Vogelmann Red Edge (VReI), Photochemical Reflectance (PRI), Red Green Ratio (GRI), and Anthocyanin Reflectance 2 (AR2I).

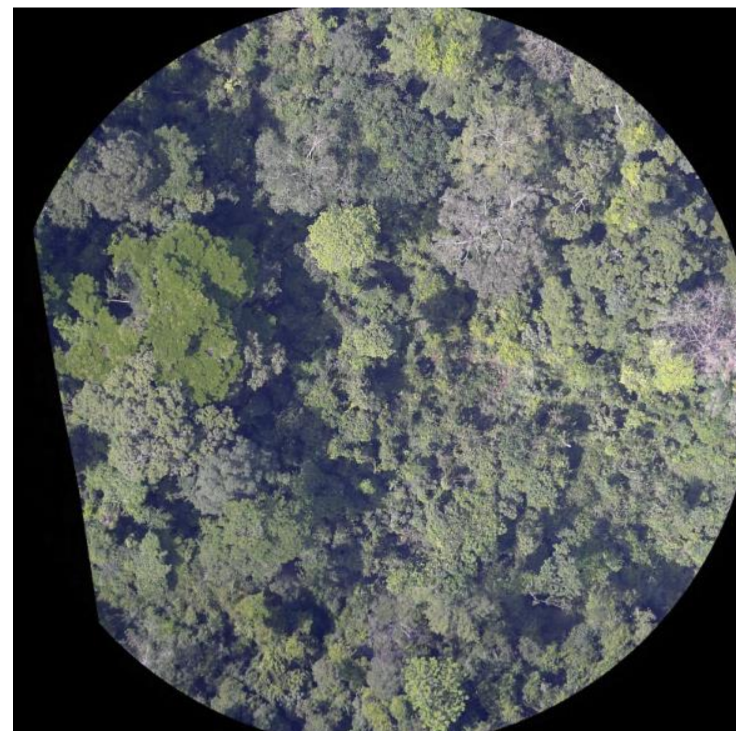
Orthophotos to support ground truth

*Rollei H25 camera equipped with a Phase One Digital Back.

* Images were georeferenced and orthorectified using the lidar DEM.

* 0.1 m spatial resolution, used as reference for visual screening during data analysis (species, damages, edge effects etc.)





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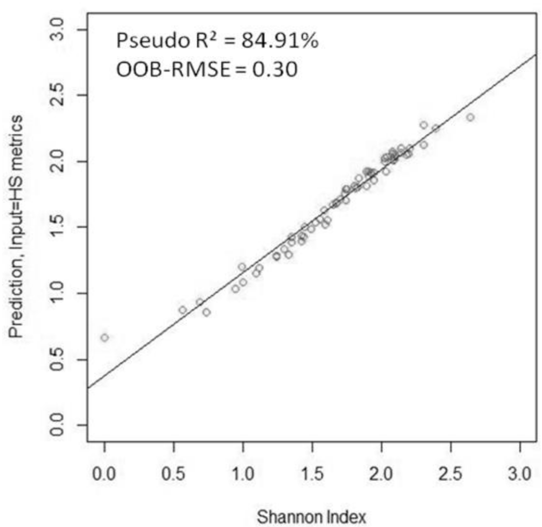
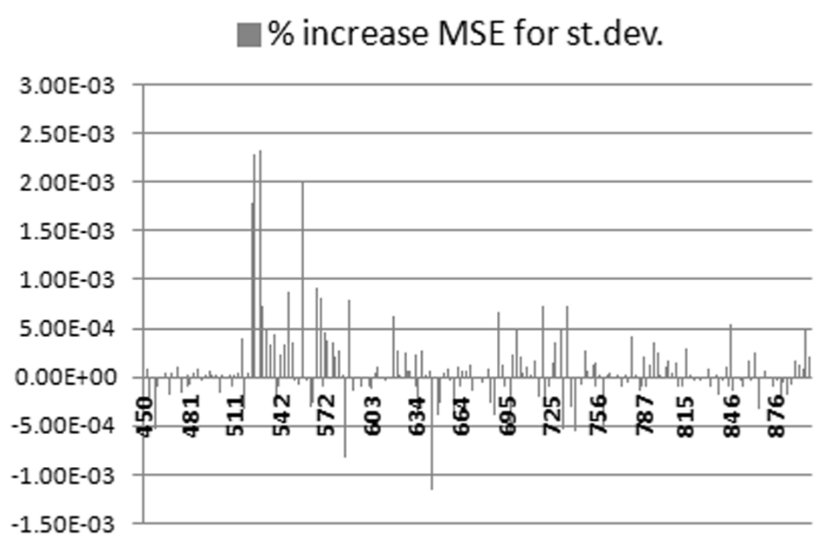
Biodiversity Mapping in a Tropical West African Forest with Airborne Hyperspectral Data

Gaia Vaglio Laurin[1,6*], Jonathan Cheung-Wai Chan[2,11], Qi Chen[3], Jeremy A. Lindsell[4,8], David A. Coomes[5], Leila Guerriero[6], Fabio Del Frate[6], Franco Miglietta[2,9,10,12], Riccardo Valentini[1,7]

Prediction of Shannon index in Gola NP

- Shannon-Wiener index can be predicted to a **good level of accuracy** using the plot-level statistics derived from hyperspectral bands and Random Forests (pseudo-R2= 84.9% and OOBRMSE = 0.30).
- HS bands were more effective than derivatives (that were supposed to suppress noise).
- Most important statistical metric was standard deviation, indicating that within-plot spectral variation is most informative in explaining diversity.





- Most important inputs were standard deviations from the green region (pigments and chlorophyll)

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Contents lists available at ScienceDirect

ISPRS Journal of Photogrammetry and Remote Sensing

journal homepage: www.elsevier.com/locate/isprsjprs

Biomass estimation in Gola NP

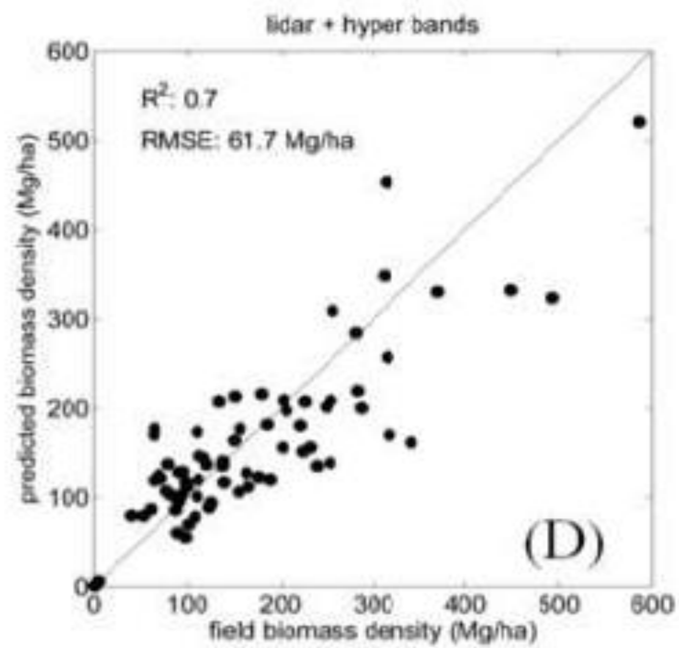
Above ground biomass estimation in an African tropical forest with lidar and hyperspectral data

Gaia Vaglio Laurin[a,f,*], Qi Chen[b], Jeremy A. Lindsell[c], David A. Coomes[d], Fabio Del Frate[f], Leila Guerriero[f], Francesco Pirotti[g], Riccardo Valentini[e,a]

- Lidar metrics alone: AGB was predicted with R^2 = 0.64 and a RMSE of 67.8 Mg ha^{-1} using Partial Least Square Regression.
- Hyperspectral bands alone R^2 = 0.36
- Addition of HS bands to lidar metrics increased R^2 = 0.70, RMSE 61.7 Mg ha^{-1}
- Replacing the hyperspectral bands with the Vis: smaller improvement

Variable importance in the projection

- VIP highest lidar scores : 40th height pct, 30th pct, mean height, 50th and 60th pct.
- VIP highest HP scores to bands in the green, and red-edge, and in NIR close to the spectra end.



Remote Sensing of Environment 176 (2016) 163–176

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Discrimination of tropical forest types, dominant species, and mapping of functional guilds by hyperspectral and simulated multispectral Sentinel-2 data

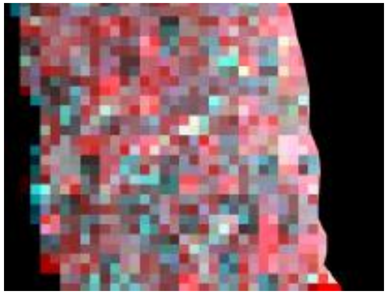
Guilds and dominant species in Ghana

We tested the ability of hyperspectral and simulated Sentinel-2 data (+ derived Vis and textures) to distinguish:

-forest types (wet, moist)

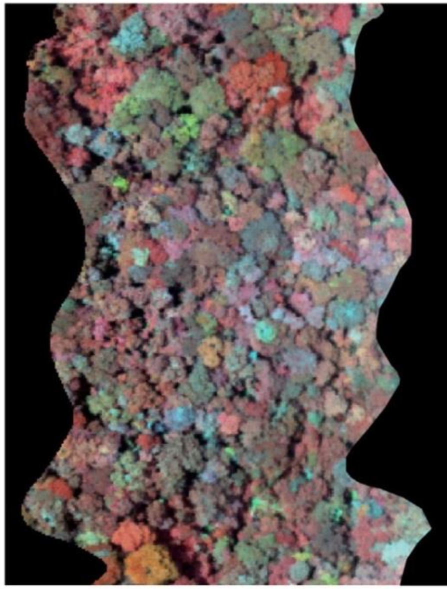
-selected dominant species (most common)

-functional guilds: Pioneer, Non Pioneer Light Demanding, and Shade Bearer.

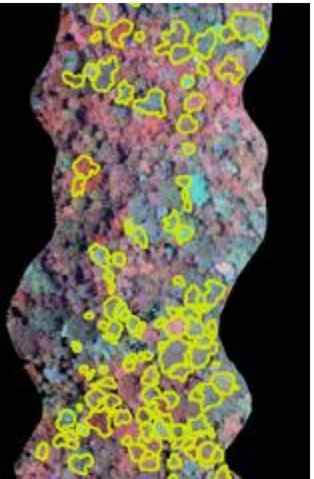


Simulated S2

ANKASA



With both hyperspectral and simulated S2 these discrimination tasks can be successfully accomplished. Results stress the importance of **texture** features, especially if using lower spectral and spatial resolution data.

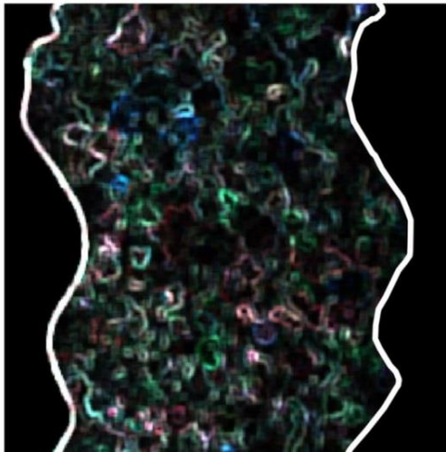


We proposed **functional guilds mapping** as an innovative approach to:

* monitor compositional changes (effects of global climate change) particularly in the tropics where mapping at species level is not feasible;

* support large-scale forest inventories (by strata)

Crown level id.



Background – agriculture case study

Preliminary research activities (together with Terrasystem) in the agriculture area using very high resolution spectral data:

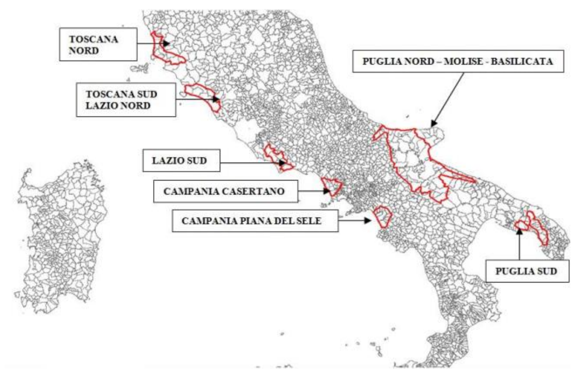
1) Crop monitoring (crop id., early forecasts of production, damage assessment)
2) Phytopatologies detection and risk analysis

TERRASYSTEM s.r.l.

Università degli Studi della Tuscia – Società Spin-off

TOMATO MONITORING

The use of satellite data (Rapideye, S2), aerial data and ground information was explored to estimate and map planted surface of italian industrial tomato.



The results indicate that high spectral resolution is often more important than high spatial resolution.
Fundamental the availability of repeated acquisitions.
Different data/results according to local environmental heterogeneity: need for area-based features calculation (VIs, textures etc.)

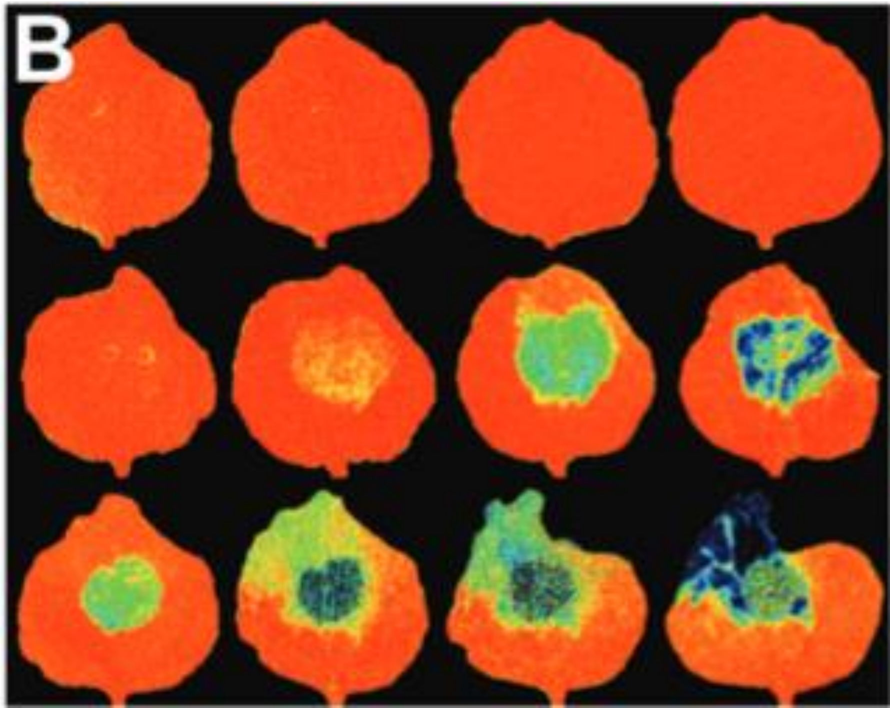
PLANT PHYTOPATOLOGIES

Kiwi diseases case study: *PSA* and *Wood fungi complex*

Preliminary tests indicate that hyperspectral data can support early detection of crops pathologies before disease is visually evident on leaves and trunks.

We are going to test the scalability of the pathogen-RS data relationship at different levels in kiwi case study: leaves, plant, crop, cultivation area - using hyperspectral data from field instruments to satellite platforms.

In fact the pathogens not only affect leaves and trunks, but alter photosynthetic performance, secondary metabolism, leaf transpiration etc., also modifying the spectral response at crop and cultivation area levels.



Change in Chl response after inoculation of tobacco with virus (from Baron et al. 2016)

Conclusions:

Hyperspectral can support innovative monitoring activities

- in agriculture: crop level monitoring, plant pathology
- in ecology: biodiversity monitoring, functional mapping

However, due to environmental heterogeneity the useful information can vary case-by-case.

Long time spent in preprocessing, dimensionality reduction, feature calculation. RS processing skills are not so widespread in the reference communities.

For data operational use is important to provide efficient tools for:

- Atmospheric correction
- Data reduction
- Feature calculation (Vegetation Indices and textures as minimum)
- Statistical advanced modeling for complex data (NN; RF, PLSR etc.)
- Data integration (e.g. SAR)